



Calhoun: The NPS Institutional Archive
DSpace Repository

Theses and Dissertations

1. Thesis and Dissertation Collection, all items

1994-03

A design rationale capture using REMAP/MM

Fuller, Charles E.; Russell, Douglas V.

Monterey, California. Naval Postgraduate School

<http://hdl.handle.net/10945/30937>

This publication is a work of the U.S. Government as defined in Title 17, United States Code, Section 101. Copyright protection is not available for this work in the United States.

Downloaded from NPS Archive: Calhoun



<http://www.nps.edu/library>

Calhoun is the Naval Postgraduate School's public access digital repository for research materials and institutional publications created by the NPS community. Calhoun is named for Professor of Mathematics Guy K. Calhoun, NPS's first appointed -- and published -- scholarly author.

Dudley Knox Library / Naval Postgraduate School
411 Dyer Road / 1 University Circle
Monterey, California USA 93943

NAVAL POSTGRADUATE SCHOOL

Monterey, California



THESIS

A Design Rationale Capture Using REMAP/MM

by

Charles E. Fuller
and
Douglas V. Russell

June, 1994

Principal Advisor:

Balasubramaniam Ramesh

Approved for public release; distribution is unlimited.

Thesis
F9265

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY CA 93943-5101

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704	
<p>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.</p>				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE June 1994		3. REPORT TYPE AND DATES COVERED Master's Thesis
4. TITLE AND SUBTITLE A DESIGN RATIONALE CAPTURE USING REMAP/MM			5. FUNDING NUMBERS	
6. AUTHOR(S) Charles E. Fuller and Douglas V. Russell				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited			12b. DISTRIBUTION CODE A	
13. ABSTRACT (maximum 200 words) Every year the Department of Defense (DoD) spends between 24 and 32 billion dollars on software alone, with maintenance costs comprising the majority of this figure. Recent studies have indicated that an effective solution to help curtail the large maintenance cost is by capturing the rationale which was used to create the systems requirements and designs, and using this information throughout the life cycle. This thesis explores the use of the REMAP/MM model for the purposes of capturing these rationale, and presents a detailed example of how REMAP/MM utilizes multimedia artifacts as tools in various systems development activities.				
14. SUBJECT TERMS REMAP/MM, Multimedia, Design Rationale			15. NUMBER OF PAGES 47	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	

Approved for public release; distribution is unlimited.
A Design Rationale Capture Using REMAP/MM

by

Charles E. Fuller
Lieutenant Commander, United States Navy
B.A., San Francisco State University, 1981

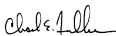
and

Douglas V. Russell
Lieutenant, United States Navy
B.S., Oregon State University, 1986

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY MANAGEMENT
from the
NAVAL POSTGRADUATE SCHOOL
June 1994

Authors:



Charles E. Fuller

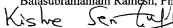


Douglas V. Russell

Approved by:



Balasubramaniam Ramesh, Principal Advisor



Kishore Sengupta, Associate Advisor



David Whipple, Chairman

Department of Systems Management

I. INTRODUCTION	1
A. THE DESIGN RATIONALE SOLUTION	1
B. WHY RATIONALE?	2
C. THE DIFFICULTY IN CAPTURING DESIGN RATIONALE	3
D. WHY MULTIMEDIA?	3
E. RATIONALE AND MULTIMEDIA	4
F. METHODOLOGY	4
G. LIMITATIONS	5
H. OUTLINE	5
II. A REMAP/MM EXAMPLE	6
A. REMAP/MM	6
Figure 1. REMAP Model.	6
B. AN EXAMPLE OF REMAP USE	7
III. IMPLEMENTATION OF THE REMAP/MM MODEL	9
A. USE OF REMAP/MM IN REQUIREMENTS ENGINEERING	9
1. Background Information	9
2. Service Operator	12
Figure 2. Video of Operator servicing calls.	12
Figure 3. Bitmap of Region One	13
Figure 4. Bitmap of Region Two.	13
Figure 5. Bitmap of Region Three.	14
Figure 6. Bitmap of Region Four.	14
3. Service Dispatcher	15
Figure 7. Video of Service Dispatcher.	15
Figure 8. Bitmap of Geographic Area.	16
4. Distribution Operator	17
Figure 9. Distribution OperatorVideo.	17
Figure 10. Bitmap of Service Tag.	18
5. Grid	19
Figure 11. Bitmap of Power Grid	19
6. Switches And Fuses	20
Figure 12. Switches and Fuses.	20
7. Current Switching Method	22

Figure 13. Video of engineer explaining current switching method	22
8. Intelligent Switches and Fuses	23
Figure 14. Video of Engineer explaining intelligent fuses.	23
B. USING REMAP/MM DURING SYSTEM ANALYSIS	24
1. Process Service Order Information	24
Figure 15. Process Service Order Information Overview.	25
a. How Should Calls Be Handled? (Issue)	25
i. Human Operator (Position)	25
ii. Personal Interaction (Argument)	25
iii. Current Answering Methods (Argument)	26
iv. Computer Routing (Position)	26
v. Voice Mail (Argument)	26
Figure 16. Video of voice mail discussion.	26
vi. Time Critical Calls (Argument)	27
b. How Are Service Orders Prioritized? (Issue)	27
i. Service Type (Position)	27
ii. Service Required (Argument)	27
iii. Computer Routing (Assumption)	27
iv. Customer Type (Position)	27
v. Specialization (Argument)	28
vi. Computer Routing (Assumption)	28
vii. Equipment (Argument)	28
viii. Computer Routing (Assumption)	28
c. How Are Service Orders Tracked? (Issue)	28
i. Current Method (Position)	28
ii. Manual Tracking (Argument)	28
iii. Computer Storage (Position)	29
iv. Automated Tracking (Argument)	29
Figure 17. Video of computer storage discussion.	29
C. USING REMAP/MM IN THE DESIGN PHASE	30
1. Process Service Tags	31
Figure 18. Process Service Tags Overview.	31
a. How to Get Customer Record? (Issue)	31

i. Entire Record (Position)	32
Figure 19. Video of Drill Down interface.	32
ii. Better Customer Relations (Argument)	33
iii. Good Public Relations (Assumption)	33
iv. Fill In Name And Address Of Customer (Position)	33
v. Faster Process (Argument)	34
Figure 20. Video of Call Status Board.	34
b. How Should The Service Operator Screen Be Organized?	34
(Issue)	
i. Nine To Ten Categories For The Operator To Choose From	34
(Position)	
ii. Current Tag Setup 9-10 Categories For The Operator To	34
Choose From (Argument)	
Figure 21. Video of current screen interface.	35
iii. Operator Fill In Text (Position)	35
iv. More Information (Argument)	35
v. Good Typists (Assumption)	35
vi. One Sized Text Box (Assumptions)	36
c. How Should The Service Tags Be Screen? (Issue)	36
i. Screen All Tags Generated In The Last 30 Minutes (Position)	36
ii. Fewer Tags Generated (Argument)	36
iii. Last 10 Tags (Position)	36
iv. Easier Method (Argument)	36
IV. RECOMMENDATIONS AND CONCLUSIONS	37
REFERENCES	39
INITIAL DISTRIBUTION LIST	40

ABSTRACT

Every year the Department of Defense (DoD) spends between 24 and 32 billion dollars on software alone, with maintenance costs comprising the majority of this figure. Recent studies have indicated that an effective solution to help curtail development and maintenance costs is to capture the rationale behind systems requirements and designs, and use this information throughout the life cycle. This thesis explores the use of REMAP/MM and multimedia based design rationale management systems. Based on a case study, a detailed example illustrating to use REMAP/MM in various systems development activities is presented.

I. INTRODUCTION

The software budget for the DoD is becoming a larger part of the entire budget each year. Currently it is estimated that DoD is spending between 24 billion and 32 billion dollars on software costs alone (USAGAO, 1992), accounting for between 8 and 11 percent of the entire DoD budget. However the amount of money the DoD spends on software does not tell the whole story. The DoD, like most software dependent companies, these days, is quickly approaching the "maintenance wall". As budgets tighten, the maintenance costs of installed systems are using up the available resources, significantly affecting new systems development (Sprague and McNurlin, 1993). During the 1970s, maintenance of software accounted for between 35 and 40 percent of the software budget for an information system organization. This number jumped to approximately 60 percent during the 1980s. It is estimated that maintenance costs today comprise 70 to 80 percent of the DoD software budget. As a result, DoD, as well as many companies, are seeking a major shift in the way they build and maintain software in order to drive maintenance costs down. (Pressman, 1992)

A. THE DESIGN RATIONALE SOLUTION

Recent research suggests that in large scale computer systems, the capture and use of the design rationale can significantly improve software development and maintenance productivity (Ramesh and Dhar, 1992). Design rationale serves multiple purposes: definition of unstated assumptions, clarification of dependencies among artifacts, decision constraints, and justification or validation of design decisions (Gruber and Russell, 1992). The effective capture and use of this design rationale should be considered a vital part of the design process.

B. WHY RATIONALE?

Over half of the cost of development of complex computer-based information systems can be attributed to decisions made in the requirements and design phases of the software development process (Walz et al, 1993). Understanding system requirements and design rationale during the later stages of the development life cycle can be useful in managing system change and can facilitate the reuse of certain components, helping to decrease software costs. For instance, the design of any system involves groups of people working through various phases of the development life cycle. Within each of the groups, every member brings individual viewpoints and expertise. Individual team members do not have all of the knowledge required for the project, and must acquire additional information before accomplishing productive work. Group interaction involves information exchange, communication, and the resolution of various issues between the team members. A primary outcome of this group interaction is design rationale; the foundation on which a project or system is built.

Due to the size of most projects, development timelines can easily stretch into several years. During this time period, most development teams experience turnover of personnel. As the individuals in the group change, the dynamics of interaction between the members also change. Additionally, the new members of the group need to be updated on the progress of the project, so that they may better understand their own role within the group. Research has shown that a great deal of the vital information given to a team during the requirements phase of development is lost (Walz et al, 1993). Design decisions can become completely lost from one meeting to the next. Even when individuals remember that a certain decision has been made,

they often find it difficult to recreate the rationale behind the decision ("Why are we doing it this way?").

C. THE DIFFICULTY IN CAPTURING DESIGN RATIONALE.

Capturing design rationale is a difficult and time consuming task. In particular, determining what aspects of design rationale are worthy of capture requires a great deal of insight and experience. The more complex the system, the more difficult it is to trace the decision process during any phase of systems development. Capture of design rationale needs to be as detailed, and complete as possible. The capture methods must prevent ambiguity in the raw data as much as possible, as well as be as unintrusive as possible. This will allow the user the opportunity to make his own interpretations of what the data means. (Ramesh and Sengupta, 1994)

D. WHY MULTIMEDIA?

The use of multimedia in capturing design rationale provides three benefits. First, multimedia is particularly useful in capturing physical gestures, body language and other forms of constructive communication among members in the design group (Ramesh and Sengupta, 1993).

Second, once captured, these narratives can then be used by different individuals for different purposes. For example, a user interested in the reasoning behind a particular artifact would use the videotape of a design session quite differently from a user interested in learning about the points of view of the respective stakeholders.

Finally, the unprocessed information that multimedia provides allows the user to interpret and assign their own evaluations of the decision process. Also, design decisions are often

characterized by assumptions that are not stated explicitly, but must be inferred from the context of the discussion. A richer context for understanding the collaboration mechanisms, process and culture in design groups can enable the user to interpret the rationale behind the creation of artifacts. (Ramesh and Sengupta, 1993).

E. RATIONALE AND MULTIMEDIA

A model that has been successfully used to structure design rationale is the Issue Based Information Systems (IBIS) model (Rittel, 1973). However, informal representations of design rationale, such as a multimedia record, have shortcomings too. Such information can not be easily indexed and retrieved. Further, the potential for automated reasoning with such knowledge is severely restricted. Recent research suggests that a semiformal representation that provides a structure to the design rationale information, in addition to multimedia, would be appropriate for design rationale capture and use (Ramesh and Sengupta, forthcoming).

The REMAP/MM system currently under development at the Naval Postgraduate School in Monterey, California, is an attempt to couple an extended IBIS model with multimedia. The REpresentation and MAintenance of Process knowledge (REMAP) provides a conceptual model and mechanism for the representation and reasoning of design rationale knowledge (Ramesh and Dhar, 1992).

F. METHODOLOGY

In this thesis, we present an example to illustrate the use of multimedia in the capture of design rationale during system development. The example consists of segments of design rationale from a system development exercise in a utility company. The example and the multimedia segments used in this document are based on a case study in the utility industry.

These detailed scenarios describe the capture of design rationale in the requirements engineering, systems analysis, and detailed design phases of system development.

G. LIMITATIONS

The example is limited in that only a few snapshots of the development process have been captured. In order to fully document and capture all of the design rationale of a project, a full-fledged longitudinal study should be carried out. This example is intended to provide a proof of concept model, not a comprehensive design rationale record. An important issue not addressed in the research is the detailed evaluation of the usefulness of multimedia design rationale capture mechanisms.

H. OUTLINE

The next section provides an overview of the REMAP/MM model and system and introduces the example. Chapter 3 provides a detailed description of REMAP/MM use in three system development activities. The focus of the discussion is to illustrate the REMAP model and multimedia in capturing and integrating design rationale. The final chapter provides the conclusion and recommendation.

II. A REMAP/MM EXAMPLE

A. REMAP/MM

The objects in the REMAP model include requirements, the primitives of IBIS (issues, positions, arguments, assumptions), as well as decisions. Requirements represent the goals or objectives of the design problem. Issues are problems, concerns, or questions relating to specific requirements. Positions are solutions which respond to an issue. Arguments are statements that support or object to positions. Assumptions behind arguments are also effectively captured. Decisions are the result of the deliberation of issues. These relationships are illustrated in Figure 1 below.

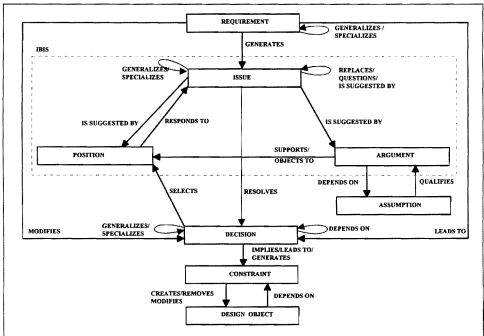


Figure 1. REMAP Model. Source Ramesh and Dhar, 1992.

REMAP/MM is a multimedia extension of the model. REMAP/MM supports the capture of design rationale by providing a graphical user interface for the design team to use during the conduct of their deliberations. It also provides a mechanism for the hyperlinking of multimedia objects to design rationale. For example, multimedia clips that elaborate issues, arguments, positions, and decisions that a design team encounters are stored in an interactive document, the REMAP/MM model. The user can explore the document by selecting buttons, highlighted text, or other objects that are linked to multimedia data such as sound clips, graphics, or even video clips. With such a document, the user can view issues or arguments that have been captured, and can follow the logic of why a decision was made.

B. AN EXAMPLE OF REMAP/MM USE

In the example, we consider a hypothetical software development team engaged in the design of complex service process ordering system for a local power and utilities company located in Duval County, Florida. The system will be using a centralized telephone answering service center that is connected to a large number of field stations via an on-line computer. The team includes all of the important stakeholders, such as management, engineering, and customer relations. The primary task of the development team is to clearly articulate the various system requirements with respect to each stakeholders point of view. Each stakeholder comes to the design team with different perspectives and requirements. For instance, the engineers are interested in efficiently screening service request tags to assist in determining power outage locations, and customer relations is concerned with being able to update clients quickly and effectively when service calls are received.

The example is intended to illustrate that by using REMAP/MM during requirements definition, analysis, and design of the system, design rationale can be effectively captured. The team will be capturing a history of the project that can be accessed and examined long after the team members have moved on to other jobs or locations. A full understanding of the design rationale of the system, along with a better insight of the systems' original intent, enhances the ability to modify the system at a later time.

III. IMPLEMENTATION OF THE REMAP/MM MODEL

A. USE OF REMAP/MM IN REQUIREMENTS ENGINEERING

During the requirements phase of a project, detailed knowledge of the background and history of the system is required in order to make sound decisions concerning the system's design requirements. For example, when a system designer is building a new user interface, s/he should have a deep understanding of how the interface would be used, and what the potential users will need to effectively perform their jobs. This portion of the example illustrates how REMAP/MM could be used during the requirements phase to effectively capture this essential background information. The following represents a hypermedia document that may be linked to the requirements hierarchy in REMAP. Highlighted words in the document have hyperlinks to multimedia segments. In this section, following a highlighted word, the section and paragraph or figure that is hyperlinked to that word is shown in parentheses. By navigating through such a document, the user can achieve a comprehensive understanding of the requirements of the system.

1. Background Information

When the power company first began providing power, its clients were located in the downtown Jacksonville area. As the city grew and expanded, outlying cities such as Jacksonville Beach, Neptune Beach, and Orange Park were incorporated into the company's power grid, making Jacksonville the largest geographical city in the United States. Today, the city has expanded to include all of Duval County, an area of nearly 840 square miles. The city has

experienced a population growth rate of nearly 28 percent in the past ten years, and power demands have increased at a similar rate.

To improve the service to this expanding city while dealing with company-wide down-sizing, the power company has determined that an automated service order processing system is the most economical solution. This new system must provide a more efficient means of handling calls from the customer for maintenance and emergency service, and allow the company to dispatch troubleshooters in the most effective manner.

Presently, the power company operates four regional centers. Each center consists of 3-5 phone **Service Operators** (see Section A,2) who answer calls from within their service area. These operators provide the customer with a variety of services, arrange electrical service start or stop dates, answer any billing question the customer might have, as well as take any trouble call information from the customer and forward the information to the service dispatcher. The **Service Dispatcher** (see Section A,3) prioritizes daily work schedules, assigns jobs to field units, and monitors the progress of all field workers. The field workers have to coordinate their work with the distribution operator. The **Distribution Operator** (see Section A, 4) coordinates all field maintenance from a central location.

The new system must allow the company to expediently dispatch their limited number of linesmen more effectively. When a service call comes into the center, a **Multipurpose Customer Service Order** (see Figure 10) or service tag is generated. This tag contains all relevant information about the customer service request. When there is a large-scale power outage, thousands of these tags can be generated. In order to dispatch the limited number of troubleshooters to the most likely source of the outage, the tags must first be manually sorted by

geographic area. Once these tags are sorted, they must then be cross-referenced with a power **Grid** (see Section A, 5) map according to substation and feeder lines . From this map, a more precise localization of where the trouble is can be determined. Since this is all performed manually, it can typically take several hours to localize and dispatch troubleshooters to the proper area.

With the **Current Switching Method** (see Section A, 7), switches must be manually opened and tested to determine if they are indeed the trouble spot, or the problem exists somewhere else along the line. Once the exact location of the trouble has been determined, the troubleshooters can begin working on the solution to the problem. With the current system, it is not uncommon for 15-24 hours to pass before power can be restored. With the installation of the **Intelligent Switches And Fuses** (see Section A, 8), the power company's goal is to completely automate the service system. Each client's address will be linked to a particular fuse or switch, allowing the computer to expediently localize the trouble spot. The Intelligent Switches And Fuses will allow for some of the repair work to be completed remotely. The distribution operator needs simply to switch the intelligent switch on or off over the phone. This will allow for more expedient troubleshooting before having to dispatch workers to the field. This new system must provide a more efficient means of handling the processing of customer maintenance request status. Once the troubleshooters are on site, they must assess the situation and notify the regional center of the estimated time that will be required to fix the problem. This information is currently first passed to the dispatcher from the linesmen. From there it is forwarded to the service center operators, time permitting, where it is then posted on a chalkboard so the operators can inform calling customers of the estimated time until their service

is restored. The linesmen then coordinate with the distribution operator to ensure that they can safely perform the maintenance without endangering other workers or themselves.

Finally, after the work has been completed, every person who called in must be contacted to determine if their power has been restored. If their power is not back on, the entire process must be repeated.

2. Service Operator

Presently, the power company operates four regional centers. **Region One** (see Figure 3). **Region Two** (see Figure 4). **Region Three** (see Figure 5). **Region Four** (see Figure 6). Each center consists of 3-5 phone operators who answer calls from within their service area. **Service Operator Video** (see Figure 2). These operators provide the customer with a variety of services, arrange electrical service start or stop dates, answer any billing question the customer might have, as well as take any trouble call information from the customer and forward the information to the service dispatcher.

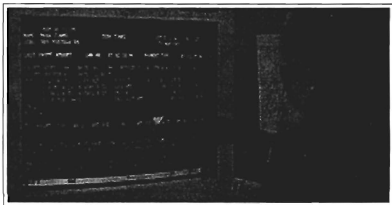


Figure 2. Video of Operator servicing calls.

The four regional service centers are divided geographically.

Region One

North of I-10, West of I-95

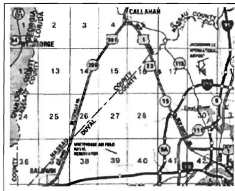


Figure 3. Bitmap of Region One.

Region Two

South of I-10, West of the St. Johns River

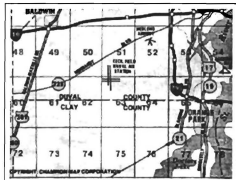


Figure 4. Bitmap of Region Two.

Region Three

North of I-10, East of I-95



Figure 5. Bitmap of Region Three.

Region Four

South of I-10, East of the St. Johns River

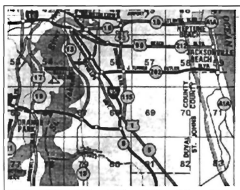


Figure 6. Bitmap of Region Four.

3. Service Dispatcher

The service dispatcher plays a vital role within the maintenance system of the power company. **Service Dispatcher Video** (see Figure 7).



Figure 7. Video of Service Dispatcher.

Due to the extremely large **Geographic Area** (see Figure 8), that the company serves, a great deal of coordination and prioritizing must take place to ensure that service is maintained and restored to as many people as possible in the shortest amount of time. In accomplishing this goal, the service dispatcher must prioritize daily work schedules, assign jobs to field units, and monitor the progress of all field workers. Additionally, during the evening hours, the service dispatcher becomes the only service operator on duty, increasing the amount of coordination required.

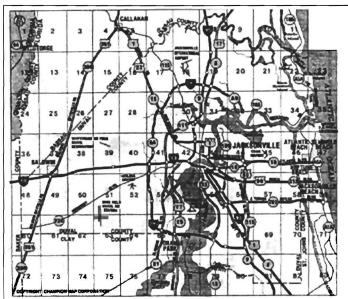


Figure 8. Bitmap of Geographic Area.

4. Distribution Operator

The distribution operator is one of the key safety coordinators for all maintenance actions.

When a field worker needs to perform maintenance on a particular section of line, the distribution operator ensures that the maintenance is performed safely. The operator does this by referencing a checklist of maintenance steps while the field worker is performing the maintenance. While doing this, s/he must also make sure that the power to the effected line is secured, and that it is safe for the field worker to proceed. **Distribution Operator Video** (see Figure 9).

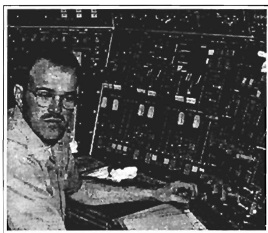


Figure 9. Distribution Operator Video.

[illegible]

5. Grid

What is commonly referred to as the "grid" is in fact the layout of all the electrical lines throughout the city. **Grid** (see Figure 11)

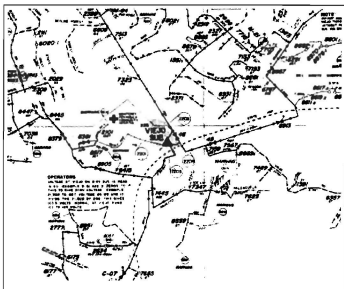


Figure 11. Bitmap of Power Grid.

The power grid is made up of substations, lines, circuit breakers, switches, and fuses.

Switches and Fuses. (see Figure 12). This grid is in turn laid over a map of the geographic area, allowing for isolation of individual residences or businesses that may be experiencing problems.

6. Switches And Fuses

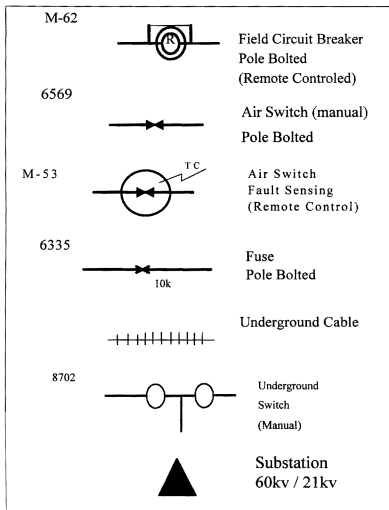


Figure 12. Switches and Fuses.

Substations are the sources for the power that goes out on a particular line. The line, typically 21,000 volts, carries the power throughout the area for distribution. Smaller, 1000 volt lines feed off of the 21 kilovolt lines and step down to distribute electricity to individual residences and business. On each of these high and low power lines are circuit breakers, switches, and fuses. These devices protect the equipment from surges and underages of power, which can cause damage to vital equipment.

7. Current Switching Method

During a global, large scale outage, workers must progressively switch on and off the switches within the system in order to isolate where the problem is located. Once the problem has been located, only then may work proceed in order to restore service. This is typically a very time consuming endeavor, requiring a great deal of coordination and manpower. When work or maintenance needs to be performed on a particular line, a field worker must go out to the circuit breakers, switches, or fuses directly upstream and downstream from the affected piece of equipment, and manually switch them off to isolate the line. Once this has been accomplished, then work on that line or piece of equipment may proceed. **Current Switching Method Video** (see Figure 13).



Figure 13. Video of engineer explaining current switching method.

8. Intelligent Switches and Fuses

The company has begun to replace its old technology **Switches And Fuses** (see Figure 12) with new, "intelligent" switches and fuses. **Intelligent Switches Video** (see Figure 14). These new devices can be controlled via the telephone, automatically switching on or off when receiving the appropriate code. This will greatly reduce the required manpower to isolate problem spots on the grid. These switches are denoted on the power grid map with the "TC" code, which means telephone controlled.



Figure 14. Video of Engineer explaining intelligent fuses.

B. USING REMAP/MM DURING SYSTEM ANALYSIS

The following section of the example illustrates REMAP/MM's use during the system analysis phase. In the scenario, the analysts are engaged in a deliberation on a requirement for processing service orders. (The deliberation in terms of REMAP primitives is shown in Figure 15.) Three issues that are raised by the team members are:

- How should calls be handled?
- How are service orders prioritized?
- How are service orders tracked?

The deliberation involves verifying positions or alternatives that solve the issues and arguments behind them, and their underlying assumptions. We briefly describe how various multimedia segments of the discussion are incorporated in the design rationale knowledge.

1. Process Service Order Information

A primary requirement is that the system should be able to handle incoming calls, establish priorities among the calls, and track the calls once they have been answered. Many customers require up to date and accurate information in order to make important, sometimes life or death, decisions. For example, a residential customer may be reliant on an electrically operated medical device. She could not survive for more than five hours without this device. This customer needs to know when the power will be restored, so a decision can be made as to whether or not to move to a location where electricity is still available.

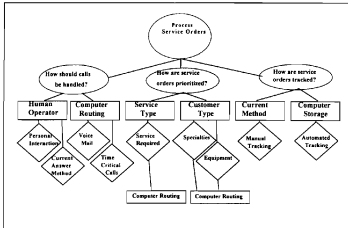


Figure 15. Process Service Order Information Overview.

a. How Should Calls Be Handled? (Issue)

The primary interface between the company and the customer is through service calls. Meeting the needs of the customer is the company's main goal, and achieving this can best be accomplished by effectively and efficiently handling incoming calls. The issue of importance here is how to handle incoming calls.

i. Human Operator (Position)

The first position is that the calls should all be handled by a human operator, who will take information and route the call manually.

ii. Personal Interaction (Argument)

The operator is the only person that the customer will interact with. All of the customer's perceptions about the company are based on their experiences with the phone operators. For this reason, human operators are preferable to automated systems. Computer systems cannot provide the personal touch that customers prefer.

iii. Current Answering Methods (Argument)

The current system of call handling is operator interaction with the customer. An automated system would add costs to the established system, and would degrade the company's public image both among its employees and the general public.

iv. Computer Routing (Position)

Computer routing allows the customer to indicated what type of service is required before having to talk with an operator.

v. Voice Mail (Argument)

A voice mail system would allow the customer to leave a message indicating what type of service is required, allowing the operators to handle more urgent calls directly. **Voice Mail Discussion** (see Figure 16).



Figure 16. Video of voice mail discussion.

vi. Time Critical Calls (Argument)

Most calls that come in to the service center are not of a critical nature.

By using a computer routing system that breaks out calls by their type (billing, maintenance, service, etc.), operators will be able to spend more time handling critical calls.

b. How Are Service Orders Prioritized? (Issue)

Due to company down-sizing and shrinking fiscal resources, the company must develop a priority scheme to better serve the customers' needs. The issue is what is the best method to prioritize incoming service requests?

i. Service Type (Position)

Calls should be prioritized by the type of service required by the customer, i.e., emergency service, billing service, or maintenance service.

ii. Service Required (Argument)

By prioritizing calls according to service type, emergency situations can be handled immediately, allowing for timely resolution of service problems. Less vital services such as billing will still be handled expediently, but when an emergency arises, appropriate resources can be immediately focused, possibly preventing damages and losses.

iii. Computer Routing (Assumption)

A computer routing system is being used to handle initial calls.

iv. Customer Type (Position)

Calls should be prioritized by the type of customer, either industrial or residential.

v. Specialization (Argument)

Prioritizing under this scheme would allow the field workers to specialize in various areas of service. Industrial customers have needs that differ from residential customers.

vi. Computer Routing (Assumption)

A computer routing system is being used to handle initial calls.

vii. Equipment (Argument)

There are different material and equipment requirements for each type of customer. By prioritizing by customer type, this equipment may be centrally managed and accounted for, reducing the company's costs.

viii. Computer Routing (Assumption)

A computer routing system is being used to handle initial calls.

c. How Are Service Orders Tracked? (Issue)

The status of all service calls must be tracked and updated, to allow for timely customer notification. How these calls should be tracked is the issue.

i. Current Method (Position)

Currently, all calls are manually tracked by placing follow-up calls for every service tag generated. This method guarantees that all customers are given return calls updating them on the status of their service

ii. Manual Tracking (Argument)

The current method of tracking orders is satisfactory, and performs well.

iii. Computer Storage (Position)

A database system of call storage should be implemented to help track orders. **Computer Storage Video** (see Figure 17).

iv. Automated Tracking (Argument)

The new system should store calls on a centralized database without actually generating the tags. When service has been restored, the computer should be able to automatically dial the customer back, and let the operator update the customer. This will greatly reduce the time demands, because the tags will not have to be manually sorted and rechecked.



Figure 17. Video of computer storage discussion.

C. USING REMAP/MM IN THE DESIGN PHASE

The following is an example use of REMAP/MM during the design phase of system development. During this phase, the development team is engaged in discussions concerning the specific design mechanisms to process service tags. The issues being considered are:

- How to get customer records?
- How should the service operator's screen be organized?
- How should service tags be screen?.

(These deliberations are shown in terms of REMAP primitives in figure 18.) These deliberations identify and solve issues concerning the design phase of the project. Included in this section are descriptions of how the multimedia segments are incorporated.

1. Process Service Tags

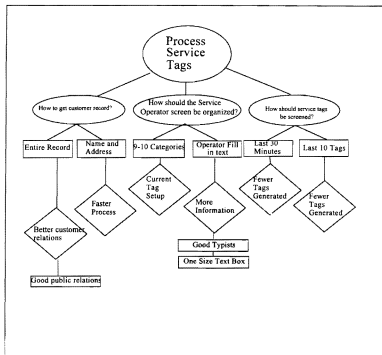


Figure 18. Process Service Tags Overview.

Automating the processing of the service tags should provide the company with the following information:

- 1) Grid customer is on.
- 2) Feeder Number of customer.
- 3) Is this an isolated event or a global outage?

It is required that the system show that it can provide the above information faster and with fewer people involved in the process.

a. How to Get Customer Record? (Issue)

A customers record contains a variety of information. Customer address, phone number, and account number are the basics. Included in the record is what grid the customer is

on, the feeder number, maintenance historical records, as well as all billing information. Some of this information is added to the newly generated tag. The issue is: How should the customers record be retrieved?

i. Entire Record (Position)

The entire record should be retrieved by the customer service operator at the time of the phone call. If a service tag is to be generated by the call, the appropriate information will be added to the tag at that time. The operator will be able to verify the correctness of the address as well.

The screenshot displays a software interface titled "Drill Down" with two main sections: "Account Data" and "Financial Data".

Account Data Section:

- Account Number: 647-8882
- Last Name: RUSSELL
- First Name: DOUGLAS
- Street Address: 1425 ARCHER STREET
- City: MONTEREY
- State: CA
- Zipcode: 93942
- Grid: 3C
- Residential: ☐
- Industrial: ☒

A map of the Monterey area is displayed, showing streets and landmarks. The address 1425 Archer Street is highlighted.

Financial Data Section:

- Financial Data: 647-8882
- Billing Name: RUSSELL COMPUTER MFG.
- Billing Address: 1425 LAINE STREET
- Billing City: MONTEREY
- Billing State: CA
- Billing Zip: 93940

At the bottom of the Financial Data section are two buttons: "View Activity" and "Close".

Figure 19. Video of Drill Down interface.

If the call is a request for billing information, it can be handled at that time. All of the customer's information is already there. Not all of the information need be displayed at all times. The operator should have the ability to "drill down" to more detailed

information as it is needed. **Drill Down Interface Video** (see Figure 19). For this reason, the information should be retrieved and ready to display for whatever the situation is.

ii. Better Customer Relations (Argument)

When a customer calls in, the call is posted on the Call Status Board. **Call Status Board Video** (see Figure 20). The operator has no idea of what the customer is calling about until she gathers more information. Because the operator is the main interface between the company and the customer, the operator should have quick and ready access to all of that customer's information. At any given time, the customer could be calling about a billing problem, a power outage, or a maintenance problem. For this reason, the operator needs to be able to instantly retrieve each of these types of data. The most efficient and expedient way of doing this is to retrieve the entire record as soon as the call is taken.

iii. Good Public Relations (Assumption)

Good public relations is important in this industry due to constantly increasing costs. The operators are the primary communicators and representatives for the company, and hence must be capable of handling nearly any situation that could arise over the phone.

iv. Fill In Name And Address Of Customer (Position)

If a service tag is to be generated from this call, the information for the tag can be obtained during the tag processing, not during the phone call. Only the name, address, and phone number of the customer are needed and these can be obtained by the operator at that time. If there is a billing problem, then just the billing information of the customer needs to be retrieved.

v. Faster Process (Argument)

By not having to retrieve the entire customer record every time a phone call comes into the service operator center, more calls can be handled, providing better service to the customer.

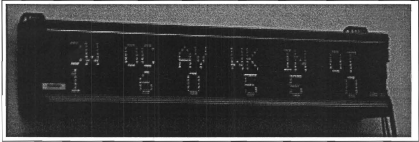


Figure 20. Video of Call Status Board.

b. How Should The Service Operator Screen Be Organized? (Issue)

Do the computer interfaces used by service operators need to be redesigned to better streamline the new automated process? **Current Screen Interface Video** (see Figure 21).

i. Nine To Ten Categories For The Operator To Choose From (Position)

The screen used by the service operators should have a list of 9 to 10 categories for the operators to classify a maintenance request under.

ii. Current Tag Setup 9-10 Categories For The Operator To Choose From (Argument)

Ninety nine percent of all problems fall under these specified categories. The maintenance people will not use any more information than the basics anyway. This is also the current interface setup. No new training required.



Figure 21. Video of current screen interface.

iii. Operator Fill In Text (Position)

The screen should have the basic address information for the operator to confirm correct. Then have a text box for the service operator to type in a description of the problem. This will allow for precise descriptions of the problem, reducing the troubleshooting time required by the field workers.

iv. More Information (Argument)

The more information describing the problem on the tag will help the maintenance people understand the problem better before actually talking to the customer themselves.

v. Good Typists (Assumption)

All the service operators are good typists, so this will not slow the process down any.

vi. One Sized Text Box (Assumptions)

One set sized text box will be able to handle any description made by a customer.

c. How Should The Service Tags Be Screened? (Issue)

The manual screening process that is used currently is just too slow. This process must be automated. Each tag will have on it the customers grid number, as well as source side device tag number. The data base must be able to screen the tags and sound an alert if there seems to be a global outage occurring.

i. Screen All Tags Generated In The Last 30 Minutes (Position)

If a tag for a complete electrical failure is generated, it needs to be compared to any tag with a similar complaint to determine if this is an isolated event or not. If not, then there is a possibility of a global failure. One method suggested to determine this would be to compare the tag to those tags generated in the last 30 minutes.

ii. Fewer Tags Generated (Argument)

This comparison will allow fewer tags to be generated if there is a global outage.

iii. Last 10 Tags (Position)

Power failure tags need to be compared with the last 10 tags regardless of time in order to detect a global failure.

iv. Easier Method (Argument)

This is a easier method to implement and it gets the same job done. Fewer tags will be generated.

IV. RECOMMENDATIONS AND CONCLUSIONS

As a system develops, the documentation that is produced becomes the formal memory of the project. What is missing from this memory is the reasoning behind the decision that produced the end product. This design rationale is a vital component of any complex design. Examining the design rationale of a complex system can lend greater insight and understanding to the system, and can be applied to future system upgrades or new projects.

Design rationale produces numerous artifacts which, when properly captured, can assist future design team members in recreating complex decisions and the reasoning behind them. The REMAP/MM model for capturing design rationale provides a graphical interface for the design team to use in their deliberations. This model, through the use of hypertext documentation, allows the team member to quickly locate issues that have been deliberated over, and examine their rationale. The user will be able to use written documents, photographs, video clips, voice clips, or any other media for capturing the design rationale.

REMAP/MM provides the user with the ability to seamlessly transition from a graphical representation of the decision process to the actual multimedia artifact that was captured during the deliberations of the issue. Such a facility should greatly increase the productivity of future designers.

The example developed for this thesis illustrates the effective capture of a wide variety of artifacts, such as video, bitmaps, and sound clips. The complexity of designing a large scale service order processing system for a large power company can easily be

imagined. A system of this complexity would typically require three to five years to fully develop and reach implementation. The example only addresses two of the relatively small sub-processes of the entire system. It is beyond the scope of this work to include a "complete" example of design rationale for this system. However, the example is intended to highlight the important characteristics of a multimedia based design rationale system. A study of such technology would consist of a longitudinal study over the entire life cycle, addressing both capture and use of design rationale.

A great deal of time and domain knowledge is required to determine what type of artifacts should be captured using multimedia. For instance video taping a design meeting often does not effectively capture all the reasoning behind certain decisions made during the meeting. Additionally, keeping the entire meeting on-line is currently impractical. Significant time and effort is required to effectively glean the vital decision process information from the vast amount of data that is communicated during a meeting. Although the example for this thesis is relatively small, hours of video and other artifacts were generated. This required a tremendous amount of editing and analysis to determine what artifacts represented useful design rationale. It is our recommendation that once a important decision has been made, the design rationale artifacts that led to that decision should be immediately documented. This would prevent the loss of important information, and allow for a more accurate representation of the decision process.

REFERENCES

1. T. Gruber and D. Russell, "Beyond the Record and Replay Paradigm for Design Rationale Support", paper presented at the AAAI '92 Workshop on Design Rationale Capture and Use, San Jose California, 15 July 1992.
2. Roger S. Pressman, "Software Engineering A Practitioner's Approach", McGraw-Hill, 1992
3. B. Ramesh and V. Dhar, "Supporting systems development using knowledge captured during requirements engineering," *IEEE Transactions on Software Engineering*, June 1992.
4. B. Ramesh and K. Sengupta, "Multimedia in a Design Rationale Decision Support System", forthcoming.
5. B. Ramesh and K. Sengupta, "REMAP/MM: Multimedia in Decision Support with Design Rationale", Decision Support Systems, 1994.
6. H. Rittel, "Dilemmas in a general theory of planning", Policy Science, 1973.
7. Ralph H. Sprague Jr., Barbara C. McNurlin, "Information Systems Management In Practice", Prentice-Hall, Inc., 1993
8. D. Walz, J. Elam, and B. Curtis, "Inside a software design team: knowledge acquisition, sharing, and integration," *Communications of the ACM*, October 1993.
9. United States General Accounting Office, "Embedded Computer Systems: Defense Does Not Know How Much It Spends on Software", July 1992.

INITIAL DISTRIBUTION LIST

	Number of Copies
1. Defense Technical Information Center Cameron Station Alexandria, Virginia 22304-6145	2
2. Library, Code 052 Naval Postgraduate School Monterey, California 93943-5002	2
3. Computer Technology, Code 37 Naval Postgraduate School Monterey, California 93943-5002	1
4. B. Ramesh, Code SM/RA Department of Systems Management Naval Postgraduate School Monterey, California 93943-5002	5
5. Kishore Sengupta, Code SM/SE Department of Systems Management Naval Postgraduate School Monterey, California 93943-5002	1
6. LCDR Charles E. Fuller 2347 Covington Creek Drive West Jacksonville, Florida 32224	2
7. LT Douglas V. Russell 15441 Windsong Lane Montclair, Virginia 22026	2

References

- Baudin, C., Gevins, J., Baya, V., & Mabogunje, A. (1992). Dedal: Using Domain Concepts to Index Engineering Design Information. *14th Annual Conference of the Cognitive Science Society*, Cognitive Science Society.
- Baudin, C., Gevins, J., Baya, V., Mabogunje, A., & Bonnet, J.-C. (1992). *The variable damper experiment* (Technical Report FIA-TR-92-08). NASA Ames Research Center, Moffett Field, CA.
- Baudin, C., Sivard, C., & Zweben, M. (1990). Recovering rationale for design changes: A knowledge-based approach. *Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics*, Los Angeles, CA, pages 745-749, IEEE.
- Baya, V., Gevins, J., Baudin, C., Mabogunje, A., Teye, G., & Leifer, L. (1992). An experimental study of design information reuse. *4th International Conference on Design Theory and Methodology*.
- Bellotti, V., & MacLean, A. (1989). *Transcription of: Two designers discussing a proposed design for a Fast Automated Teller Machine* (Internal Technical Report AMODEUS RP6/DOC1). Rank Xerox EuroPARC.
- Boose, J. H., Bradshaw, J., Koszerek, J. L., & Shema, D. B. (1992). Better group decisions: Using knowledge acquisition techniques to build richer decision models. *Hawaii International Conference on System Sciences*.
- Boose, J. H., Shema, D. B., & Bradshaw, J. M. (1991). Knowledge-based design rationale capture: Automating engineering trade studies. In M. Green (Eds.), *Knowledge Aided Design*. London: Academic Press. in press.
- Bowen, J., & Bahler, D. (1993). Constraint-based software for concurrent engineering. *IEEE Computer*, 26(1), 66-68.
- Brown, D. C., & Bansal, R. (1991). Using Design History Systems for Technology Transfer. *Proceedings of Computer-Aided Product Development, MIT-JSME Workshop*, MIT, Cambridge, MA, 1989, Computer Science Department, Worcester Polytechnic Institute.
- Carroll, J. M., & Moran, T. P. (1991). Special Issue on Design Rationale. *Human-Computer Interaction*, 6(3-4), .
- Chandrasekaran, B., Goel, A. K., & Iwasaki, Y. (1993). Functional representation as design rationale. *IEEE Computer*, 26(1), 48-56.
- Chen, A., Dietterich, T. G., & Ullman, D. G. (1991). A computer-based design history tool. *NSF Design and Manufacturing Conference*, Austin, Texas, pages 985-994.
- Conklin, J., & Yakemovic, K. B. (1991). A Process-oriented Paradigm for Design Rationale. *Human Computer Interaction*, 6 (3/4), 357-392.
- Cutkosky, M., Engelmere, R. S., Fikes, R. E., Gruber, T. R., Genesereth, M. R., Mark, W. S., Tenenbaum, J. M., & Weber, J. C. (1993). PACT: An experiment in integrating concurrent engineering systems. *IEEE Computer*, 26(1), 28-37.
- Falkenhainer, B., & Forbus, K. (1992). Self-explanatory simulations : Scaling up to large models. *Proceedings of the Tenth National Conference on Artificial Intelligence*, San Jose, CA, pages 685-690, AAAI press / MIT press.
- Falkenhainer, B., & Forbus, K. D. (1991). Compositional modeling: Finding the right model for the job. *Artificial Intelligence*, 51, 95-143.
- Fischer, G., Lemke, A. C., Mastaglio, T., & Morch, A. I. (1990). Using Critics to Empower Users. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI'90)*, pages 337-347.
- Fischer, G., Lemke, A. C., McCall, R., & Morch, A. I. (1991). Making Argumentation Serve Design. *Human-Computer Interaction*, 6(3/4), 393-420.

- Garcia, A. C. B. (1991). Selections from Request for Rationale materials in HVAC design. Stanford University, Department of Civil Engineering. Personal Communication, November, 1991.
- Garcia, A. C. B. (1992). *Active Design Documentation*. Doctoral Dissertation, Stanford University. Available as a technical report from the Department of Civil Engineering.
- Garcia, A. C. B., & Howard, H. C. (1992). Acquiring design knowledge through design decision justification. *Artificial Intelligence for Engineering, Design, and Analysis in Manufacturing*, 6(1), 59-71.
- Goel, A., & Chandrasekaran, B. (1989). Functional representation of designs and redesign problem solving. *IJCAI-89*, Detroit, pages 1388-1394.
- Gruber, T. R. (1990). *Model-based Explanation of Design Rationale* (Technical Report KSL-90-33). Knowledge Systems Laboratory, Stanford University. Also appears in *Proceedings of the AAAI-90 Workshop on Explanation*, Boston, MA, July 1990.
- Gruber, T. R. (1991). Interactive acquisition of justifications: Learning "why" by being told "what". *IEEE Expert*, 6(4), 65-75, August.
- Gruber, T. R., Boose, J., Baudin, C., & Weber, J. (1991). Design rationale capture as knowledge acquisition: Tradeoffs in the design of interactive tools. In L. Birnbaum & G. Collins (Eds.), *Machine Learning: Proceedings of the Eighth International Workshop*, Chicago, pages 3-12, Morgan Kaufmann.
- Gruber, T. R., & Gautier, P. O. (1992). *Machine-generated Explanations of Engineering Models: A compositional modeling approach* (Technical Report KSL 92-88). Knowledge Systems Laboratory, Stanford University. Submitted to *IJCAI'93*.
- Gruber, T. R., & Russell, D. M. (1990). *Design Knowledge and Design Rationale: A Framework for Representation, Capture, and Use* (Technical Report KSL 90-45). Knowledge Systems Laboratory, Stanford University.
- Gruber, T. R., & Russell, D. M. (1992). *Derivation and Use of Design Rationale Information as Expressed by Designers* (Technical Report KSL-92-64). Knowledge Systems Laboratory, Stanford University.
- Gruber, T. R., Tenenbaum, J. M., & Weber, J. C. (1992). Toward a knowledge medium for collaborative product development. In J. S. Gero (Eds.), *Artificial Intelligence in Design '92*. Boston: Kluwer Academic Publishers.
- Guindon, R. (1990). Knowledge exploited by experts during software system design. *International Journal of Man-Machine Studies*, 33, 279-304.
- Howard, R., & Matheson, J. E. (Eds.). (1984). *Readings on the Principles and Applications of Decision Analysts*. Menlo Park, CA: Strategic Decisions Group.
- Hwang, T. S., & Ullman, D. G. (1990). The design capture system: Capturing back-of-the-envelope sketches. *International Conference on Engineering Design (ICED 90)*, Dubrovnik, Yugoslavia.
- Iwasaki, Y., & Low, C. M. (1991). *Model Generation and Simulation of Device Behavior with Continuous and Discrete Changes* (Technical Report KSL-91-69). Stanford University, Knowledge Systems Laboratory. To appear in *Intelligent Systems Engineering*, 1993.
- Kuffner, T. A. (1990). *Mechanical Design History Content: The Information Requests of Design Engineers*. Master's thesis, Oregon State University.
- Kuffner, T. A., & Ullman, D. G. (1990). The information requests of mechanical design engineers. *Design Studies*, 12(1), 42-50.
- Kunz, W., & Rittel, H. (1970). *Issues as Elements of Information Systems Center for Planning and Development Research*, University of California at Berkeley.
- Lakin, F., Wambaugh, H., Leifer, L., Cannon, D., & Sivard, C. (1989). The electronic design notebook: Performing medium and processing medium. *Visual Computer: International Journal of Computer Graphics*, 5(4), 214-226.

- Lee, J. (1990). SIBYL: A tool for managing group decision rationale. *Proceedings of the conference on Computer Supported Cooperative Work (CSCW-90)*, Los Angeles, pages 79-92.
- Lee, J., & Lai, K.-Y. (1991). *A Comparative Analysis of Design Rationale Representations* (Technical Report 121). MIT Center for Coordination Science.
- Leifer, L., Baudin, C., Gevins, J., Toye, G., Baya, V., & Mabogunje, A. (1992). A Tool and Protocol for Developing Reusable Design Knowledge. *First AIAA Aerospace Design Conference*.
- Lubars, M. D. (1991). Representing design dependencies in an issue-based style. *IEEE Software*, 8(4), July, 81-89.
- MacLean, A., Young, R., Bellotti, V., & Moran, T. (1991). Questions, Options, and Criteria: Elements of A Design Rationale for User Interfaces. *Human Computer Interaction*, 6(3/4), 201-250.
- Mark, W., & Schlossberg, J. (1991). Interactive acquisition of design decisions. *Proceedings of the Knowledge Acquisition for Knowledge-Based Systems Workshop*, Banff, Canada.
- Mark, W., Tyler, S., McGuire, J., & Schlossberg, J. (1992). Commitment-based software development. *IEEE Transactions on Software Engineering*, 18(10), 870-885.
- McCall, R. (1986). Issue-serve systems: A descriptive theory for design. *Design Methods and Theories*, 20(8), 443-458.
- Mitchell, T. M., Keller, R. M., & Kedar-Cabelli, S. T. (1986). Explanation-based generalization: A unifying view. *Machine Learning*, 2(1), 46-80.
- Mostow, J. (1989). Design by derivational analogy: Issues in the automated replay of design plans. *Artificial Intelligence*, 40, 119-184.
- Nayak, P. P. (1992). *Automated modeling of physical systems*. Ph.D. Thesis, Computer Science Department, Stanford University. Technical report STAN-CS-92-1443.
- Newman, S. E., & Marshall, C. C. (1990). *Pushing Toulman too far: Learning from an argumentation representation scheme* Technical Report Xerox PARC.
- Palmer, R. S., & Cramer, J. F. (1991). *SIMLAB: Automatically creating physical systems simulators* (Technical Report TR 91-1246). Department of Computer Science, Cornell University.
- Petrie, C. (1990). *REDUX: An Overview* (Technical Report TR ACT-RA-314-90). Microelectronics and Computer Technology Corporation.
- Pirolli, P., & Goel, V. (1989). Three Transcripts of design protocols: (1) Architecture, (2) Mechanical Engineering, (3) Instructional Design. UC Berkeley, School of Education. Personal correspondence, December, 1989.
- Ramesh, B., & Dhar, V. (1992). Supporting systems development using knowledge captured during requirements engineering. *IEEE Transactions on Software Engineering*, (June), 18(6), 498-510.
- Rosson, M. B., & Carroll, J. M. (1992). *Extending the Task-Artifact Framework: Scenario-based Design of Smalltalk Applications* (Research Report RC 17852 (#78516)). IBM Research Division.
- Russell, D. M., Burton, R. R., Jordan, D. S., Jensen, A. M., Rogers, R. A., & Cohen, J. (1990). Creating instruction with IDE: Tools for instructional designers. *Intelligent Tutoring*, 1(1), 3-16.
- Shema, D., Bradshaw, J., Covington, S., & Boose, J. (1990). Design knowledge capture and alternative generation using possibility tables in CANARD. *Knowledge Acquisition*, 2(4), 345-364.
- Uejio, W. H. (1990). Electronic Design Notebook for the DARPA Initiative in Concurrent Engineering. *Proceedings of the Second Annual Concurrent Engineering Conference*, Morgantown, WV, pages 349-362.

- Uejio, W. H., Carmody, S., & Ross, B. (1991). An electronic project notebook from the electronic design notebook (EDN). *Proceedings of the Third National Symposium on Concurrent Engineering*, Washington, D.C., pages 527-535.
- Wolfram, S. (1991). *Mathematica: A System for doing Mathematics by Computer*. Menlo Park, CA: Addison-Wesley.
- Yakemovic, K. B., & Conklin, J. (1990). Observations on a Commercial Use of an Issue-Based Information System. *Proceedings of Computer Supported Cooperative Work*, Los Angeles, CA.

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY CA 93943-5101



GAYLORD S

DUDLEY KNOX LIBRARY



3 2768 00019601 8